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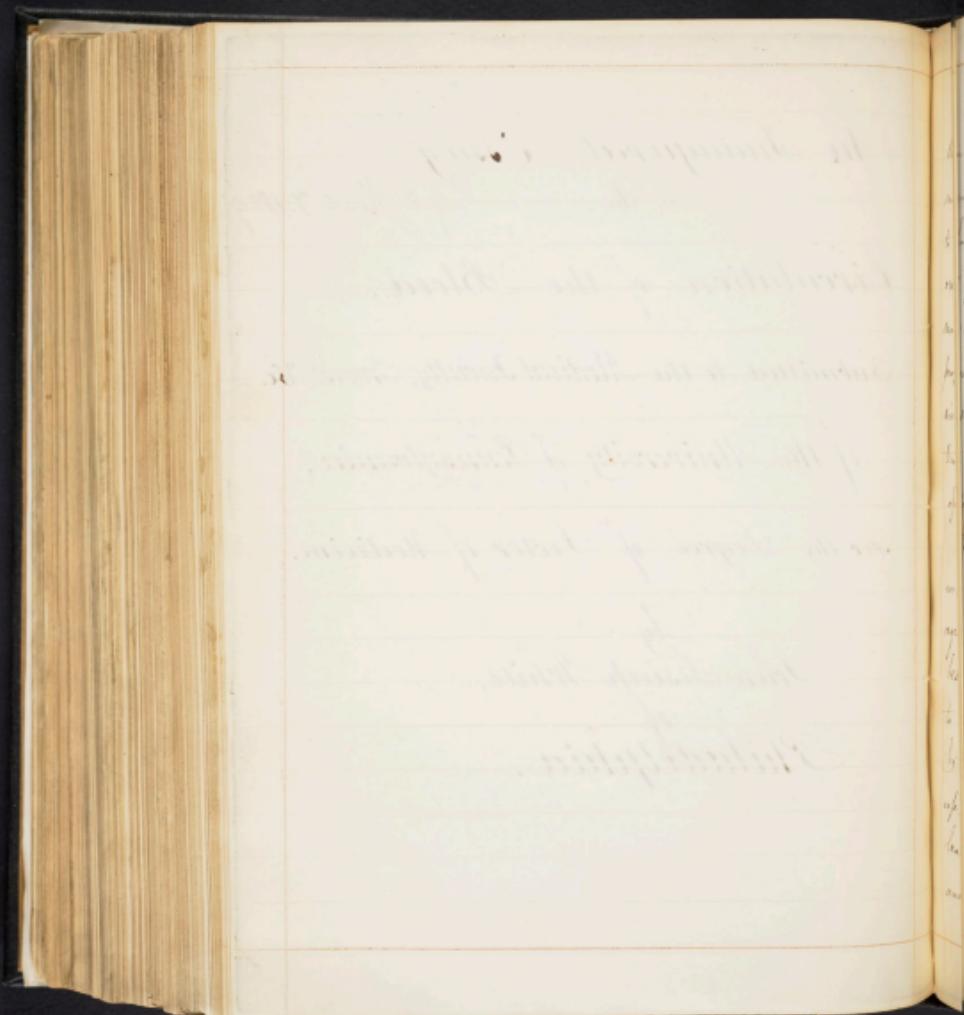
63 Pine St. #15

An Inaugural Essay
on the ^{Paid March 7. 1829}
^{very good -}
Circulation of the Blood.

Submitted to the Medical Faculty, Friends, &c.

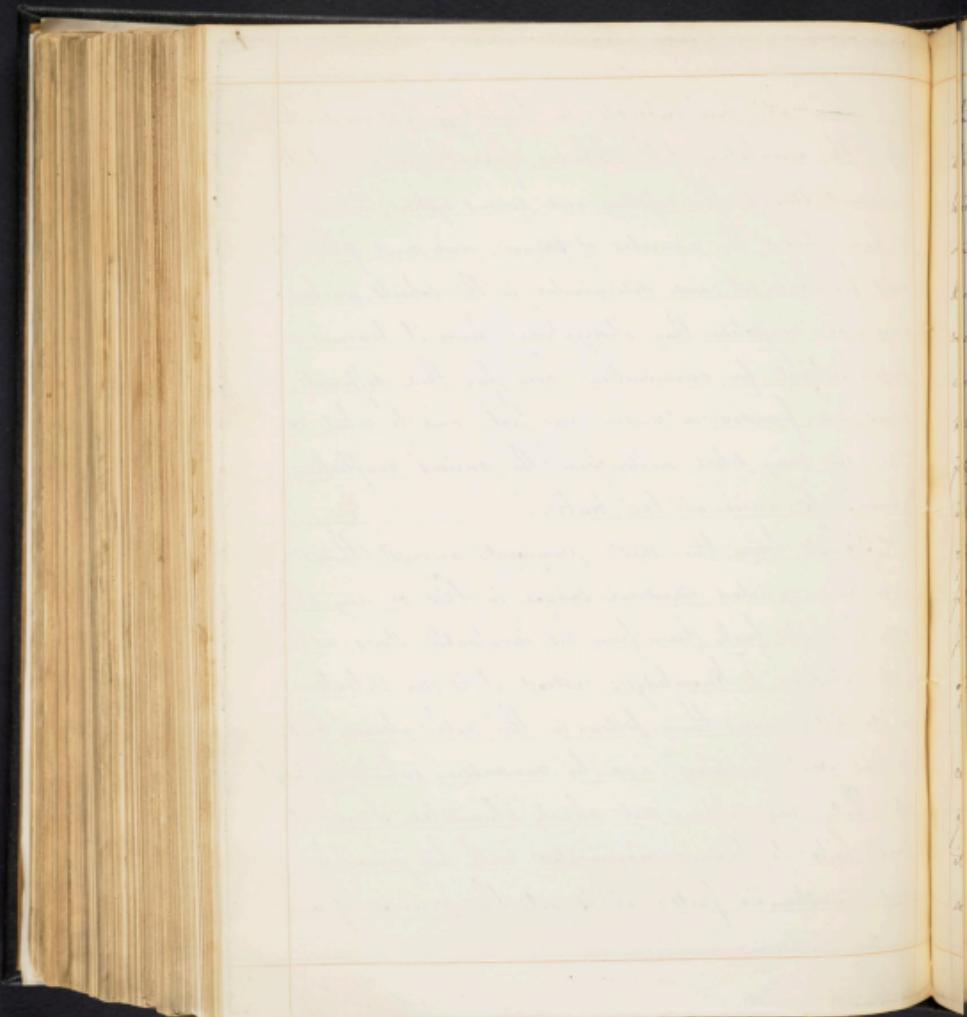
of the University of Pennsylvania,
for the Degree of Doctor of Medicine.

by
John Sosiah White,
of
Philadelphia.



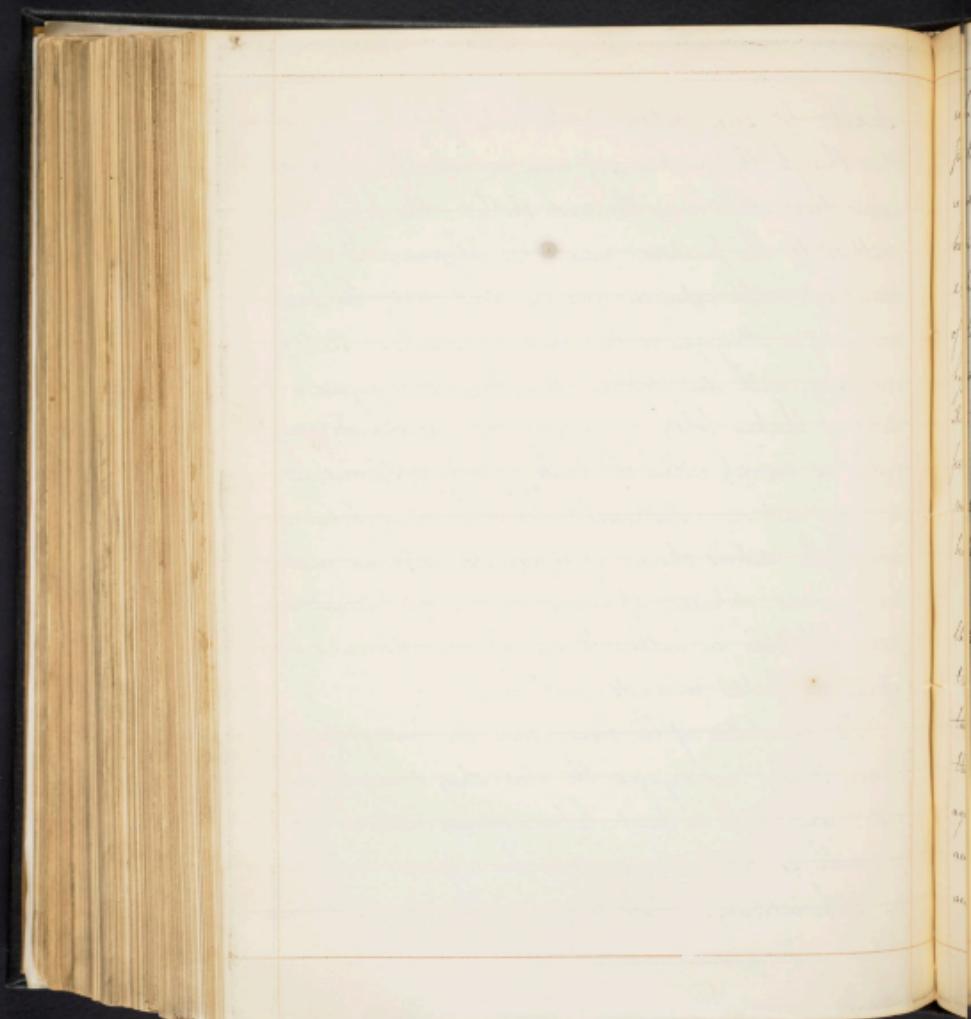
There are few subjects in Physiology, less understood than the circulation of the blood; from the intricacy of its movement through the capillary and venous systems, it seems to have eluded the researches of science, and most of the theories formed on it, and disseminated in the schools, are based more upon conjecture than observation: hence it becomes a proper subject for examination, how far these different views are founded on reason and fact, and to what extent we may detect matter from the various conflicting opinions to arrive at the truth.

Pichat being the most prominent amongst those who have enriched Medical Science in this, or any other age, I shall freely draw from his invaluable stores, as the best repository of knowledge; instead it is my intention to do little more than follow in the path already beaten by this great luminary, and by canvassing whatever stands up, that may appear not clearly elucidated, I can at least hope to become acquainted with his principles and inestimable facts; it is not the province of a



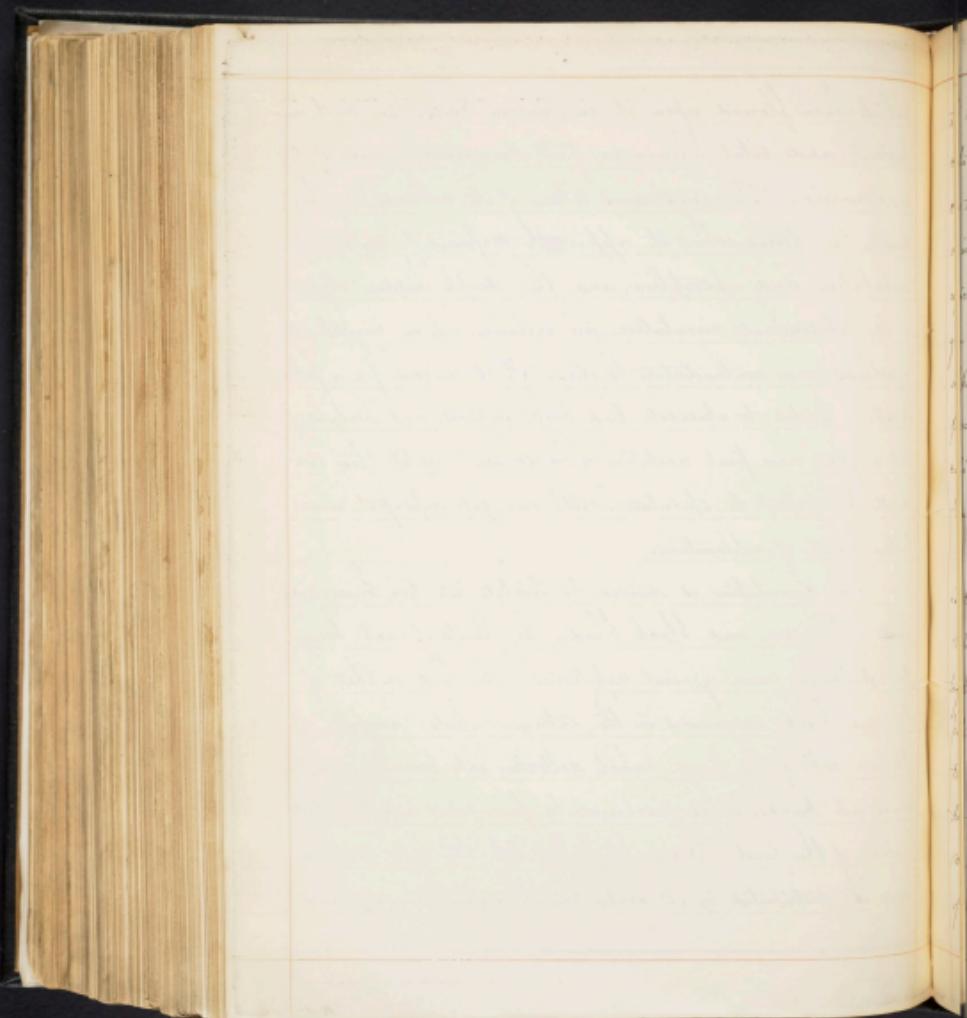
student, to seize boldly on the hint of discovery, and steer through the quicksands of error, or avoid the dark delusions that often vex the most skilful; this belongs undoubtedly to the practised mind of the physician; it requires knowledge, ample experience, and the wisest tact; the perseverance of a Moryague, or the genius of a Fluvius. But, by examining, with due deference their theories, to acquire a habit of thinking boldly, of concluding correctly, and deciding justly, is certainly within the limits of his capacity, and his imperative duty.— Impressed with these views, I have seized the dubious chance, of experimenting with an unskillful eye, and deficient apparatus, for the less brilliant prospect, of following an author through his own discoveries, and offering my feeble comments upon them.

The circulation of the blood, since the time of its discoverer, Harvey, has engaged the close study of every physiologist; and with so much labour already bestowed upon it, with so little success, may be supposed to possess no little intricacy. Notwithstanding the streams of latent



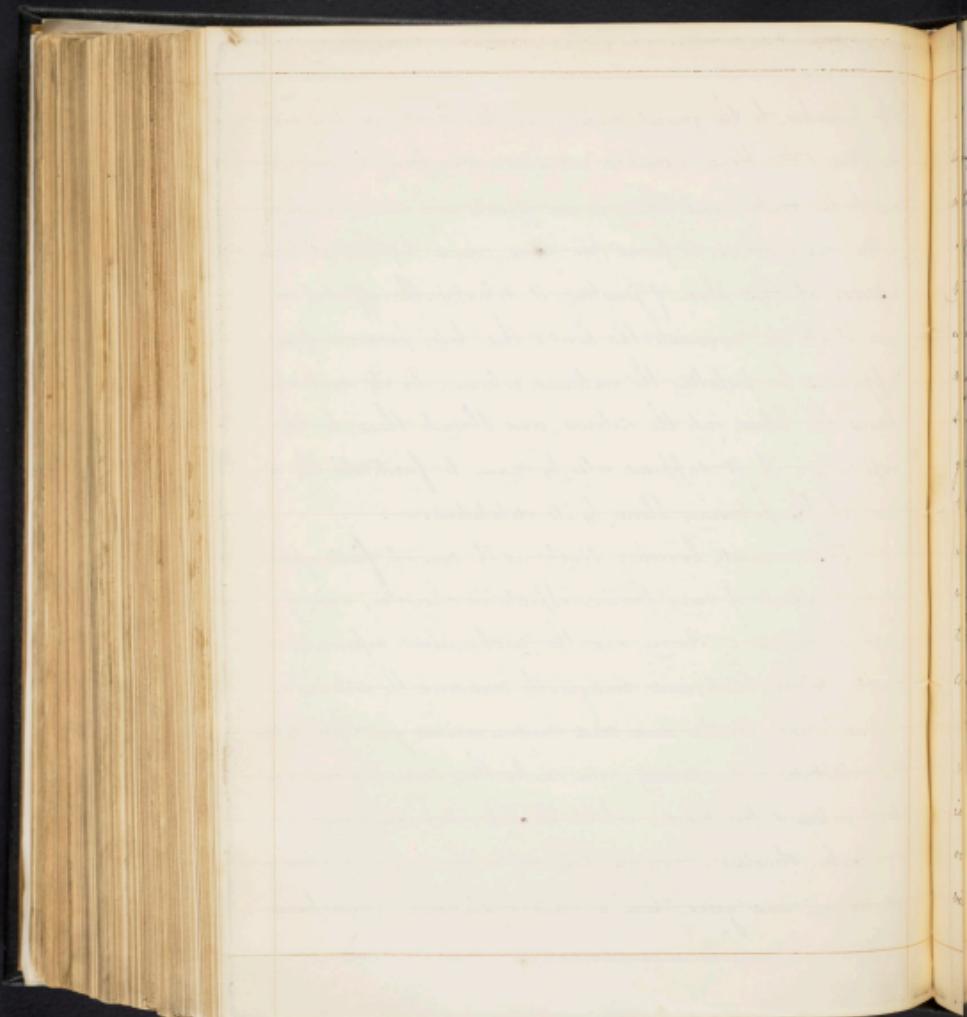
which have flowed upon it in modern times, the most important and total phenomena of its movement, remain yet undiscovered. The mysterious return of its columns to the heart, the offices which it apparently performs of nutrition, exhalation, and absorption, and the deeply hidden objects of the abdominal circulation, are explained only on conjectural hypotheses and contradictory theories. It is reserved for a future writer or Biobat, to elucidate these knotty subjects, and perhaps often a great and final resolution in our science: until then we must be content to speculate, with our yet imperfect and broken chain of explanations.

The circulation is divided by Biobat into two kinds: viz. that of the red and black blood, the limits of each, being the pulmonary and general capillaries: the first or that of the red blood, commences in the extreme vessels, ramifying on the air cells of the lungs, which collecting into branches, and those again into trunks, it is discharged by four veins into the left auricle of the heart; thence it passes into the left ventricle and is distributed by its contraction through the aorta and



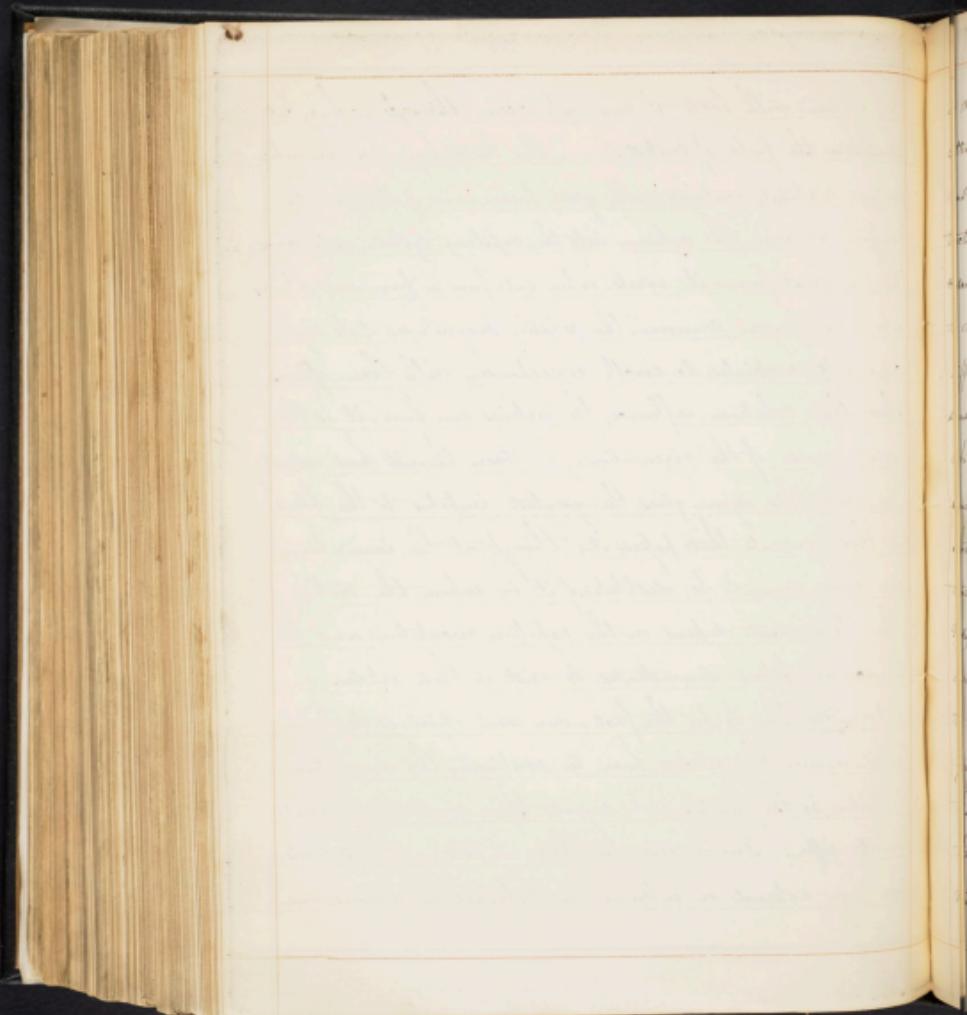
its branches, to the general capillaries; the route in this circulation of the blood, resembles radii proceeding from the surfaces to the centre, and trace to an opposite and similar surface or in other words, it forms two cones, joined together at their apices: at this place of junction, is situated the effluent organ of all its movements, the heart; this, being possessed of an apparatus for propelling the contained column, by its contraction forces the blood into the arteries, and through them, to the capillaries: it is supposed also, by many, to facilitate the return of the pulmonary blood by its dilatation.

This movement, however, simple as it may at first appear, is the subject of many theories, opposite in character, and of high pretensions. Harvey, and the mechanicians, referred it altogether to the heart, and consequently considered the arteries as passive tubes: Hunter and most modern writers give these latter the attributes of muscularity, and make them serve materially in the motion of the blood, whilst Riolan, despising them of muscular structure, considers their contraction cuts the effect of tension, and gives them a middle station. Mesmer and

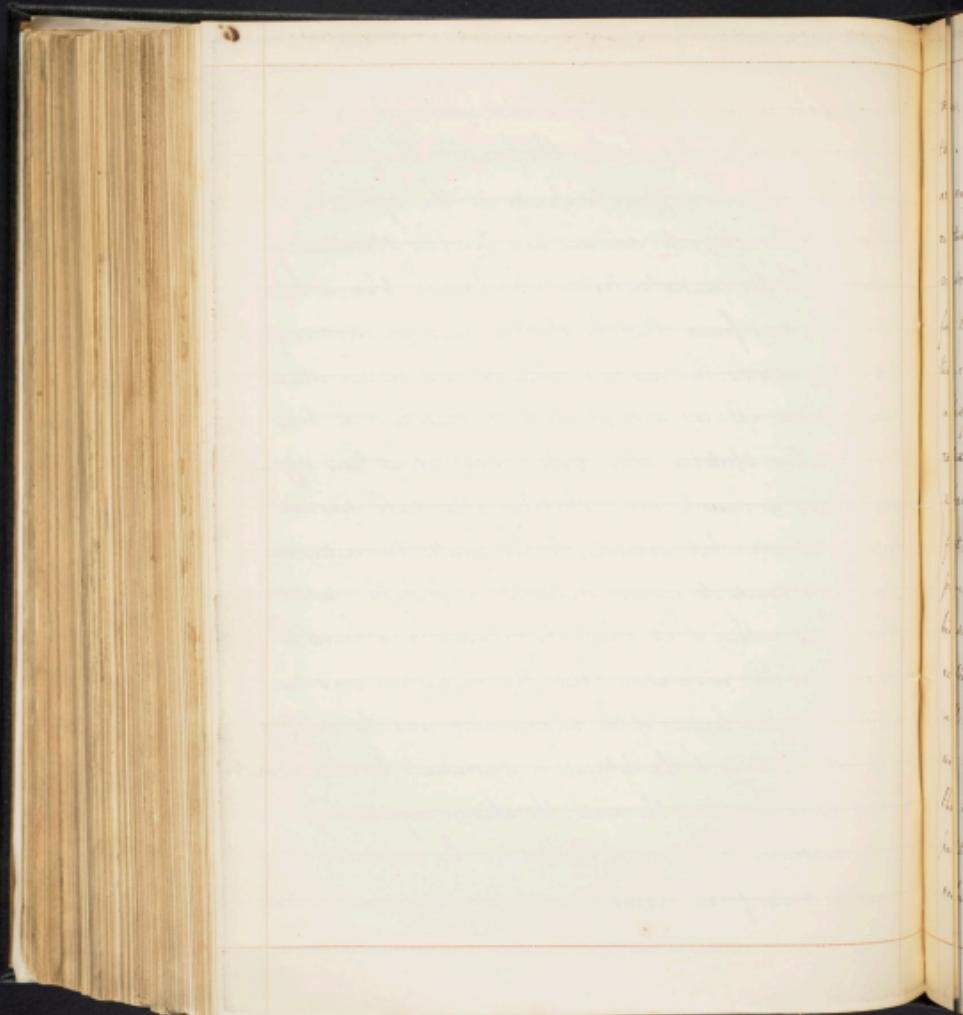


as I am with foots, I can only view through a glass at
one place the field of arteries. — The heart, being of a muscular
nature, certainly contracts, with great force, and of itself would
suffice to throw the column into the capillary system, as it proves
by the great power it exerts when cut from a frog, and placed
upon the finger; moreover, the relative magnitudes of its right
and left ventricles, so exactly corresponding with their offices
show, that whatever influence the arteries may have, it is the
great cause of the circulation. — Every theorist has admitted,
that this organ, gives the greatest impetus to the blood
in those animals that possess it; though at the same time
we know many to be destitute of it in which the motion of
the blood must depend on the capillary circulation, and the
muscular fibres demonstrated to exist in those arteries.

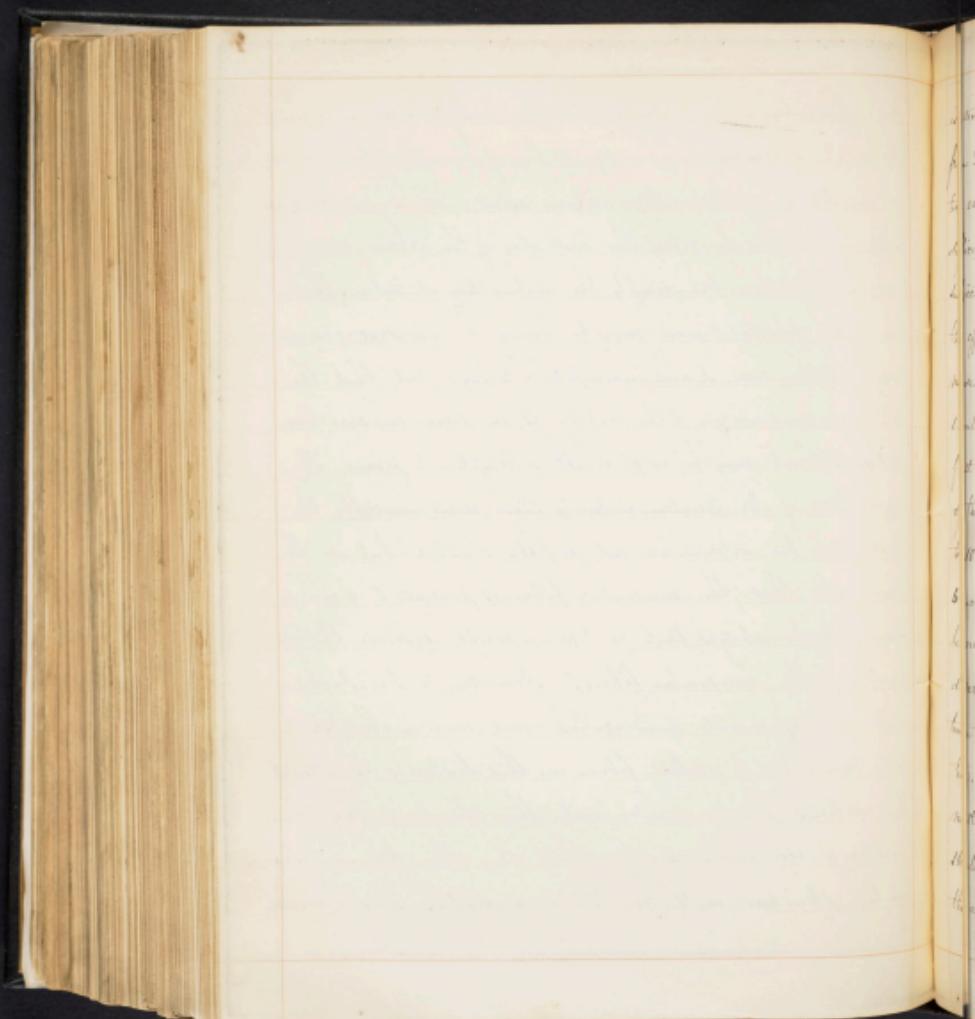
Admitting this to be the fact, our next object is, to know
what agency the arteries have in containing the momentum
imparted by the heart. — As regards their construction, au-
thorities differ: Hunter describes them as tubes with 3 coats,
viz:— an external or cellular, an internal or nervous, and



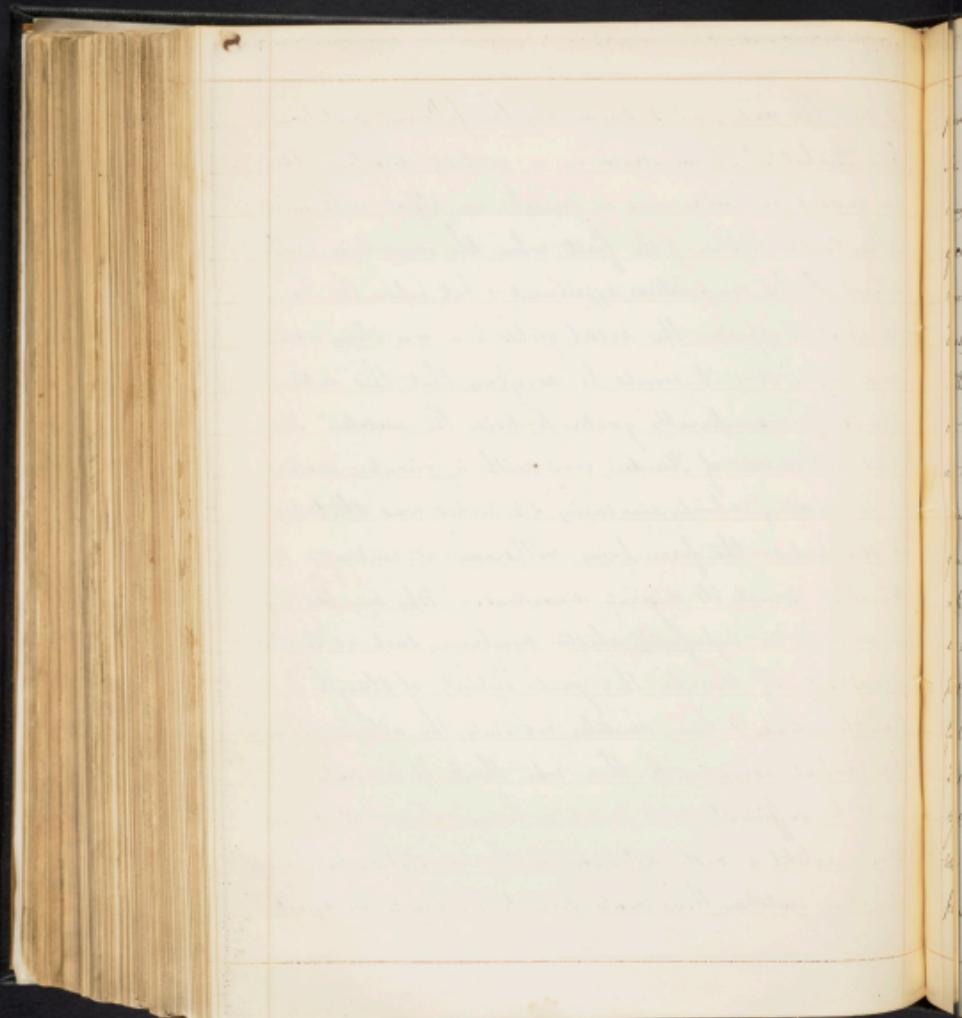
a middle, which he considers, elastic and muscular, the latter or muscular being within the former. The fibres of this muscular coat, he supposes to operate, in the systole, or contraction of an artery; to determine how far this structure coincided, with the muscular texture elsewhere, he bled a horse to death, and found that by stretching transversely, sections of different arteries, did not return to their original dimensions: hence appeared a similarity to the muscles of the body, which when stretched after death, do not resume their original dimensions: a muscle, once stretched after death, does not shorten at all: but according to his results the artery contracted to nearly its original diameter: a perfect elastic body loses nothing of its shape by extension, and hence he arrived at the conclusion, that the contraction was due to the exterior lamina of the middle coat, and its want of perfect elasticity to the internal or muscular: he also observed that in a section of the aorta, the elastic projected beyond the muscular, lamina. — Bidot, in his account of the middle tunic of the arteries, describes it, as a peculiar texture



tive, partaking of the fibrous & elastic, though belonging to neither. It is composed, according to him, of circular fibres, which are capable of distension to a certain extent, but beyond this are ruptured; to this he refers the contraction of the arteries, not from muscular motion, but simply, the contractility of texture. How far these opposite views, may be owing to imperfect observation on either side, I am incompetent to say; but that the alledged muscularity of the arteries, is in some measure overrated, I think may be well worth attempting to prove. The experiments of Mr. Hunter certainly show, what must be the fact, that the arteries are not perfectly elastic; but do they prove also that the muscular fibre is present? Even he himself acknowledges that he "never could discover the direction of the muscular fibres." According to Dr. Jackson all the experiments of Vergelius and modern chemists have not been able to detect fibres in this texture; Besides, if the arteries possess muscularity, they should sustain comparatively the same weight, that any other known muscular structure will in life and death. This however

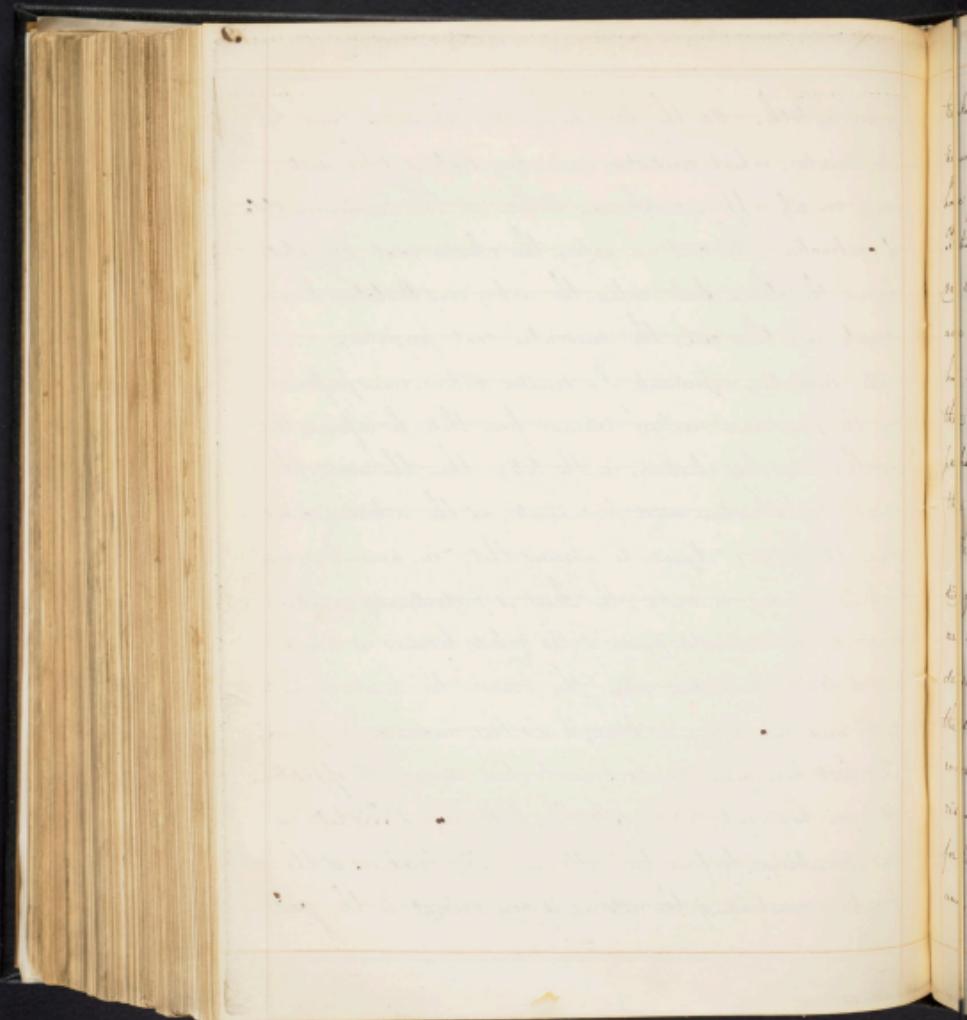


is not the case," as it is shown by the following quotation from Pichot. "If we draw in a contrary direction, the two ends of an artery and a muscle, we effect with more difficulty the rupture of the first, when the dead body, is the subject of this comparative experiment; but upon the living the effect is opposite: the vessel yields to a very strong action made upon it: it would be necessary that this action should be incomparably greater to divide the muscle." The first experiment of Hunter was with a circular section of the artery which, measuring 5 $\frac{1}{2}$ inches was stretched to 10 $\frac{1}{2}$ inches: the force being withdrawn, it contracted to 6 inches: nearly its original dimensions. Why may not this be owing to an imperfectly elastic membrane, such as Pichot describes? If there be that great disparity of strength between the dead & living muscle, especially the arterial structure, which according to those who think it muscular, must be sufficiently so to propel a heavy column of blood, should exhibit a vast difference in the two states; but, from the above quotation, there would seem to be, nearly an equal



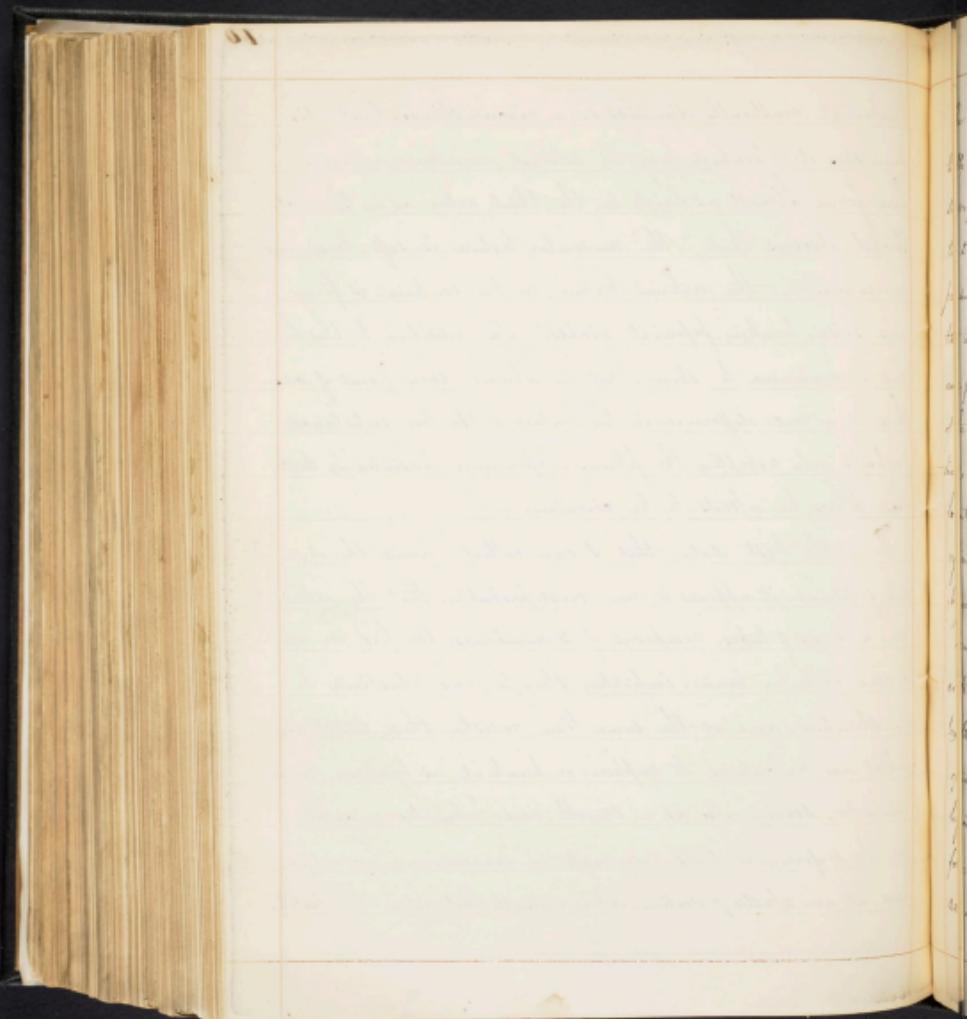
power is lost. On the other hand, the experiments tried by Mr. Quater, which consisted in making sections of the aorta, may conceivably appear conclusive. When at the minimum state of contraction, he cut an artery, the elastic coat projected beyond the other; but when the artery was stretched tautly and then cut, the muscular coat projected.

The succeeding experiments of a similar nature, were performed on the gluteal and axillary arteries; from these he infers that as there was less elasticity, in the latter, than the aorta, the muscular structure must predominate, as the arteries receive from the heart: Again he observes that, "in animals, whose arteries are very muscular, the heart is proportionally weaker, so that the muscular power of the vessels becomes a second part to the heart, acting when the power of the heart, begins to fail, and increasing in strength as that increases in power." This last paragraph would seem to bear down all oppositions if we have only to consult the first page of Pritchard, on this membrane, he finds the following: "The thickness of the peculiar membrane of the arteries, is very evident in the great



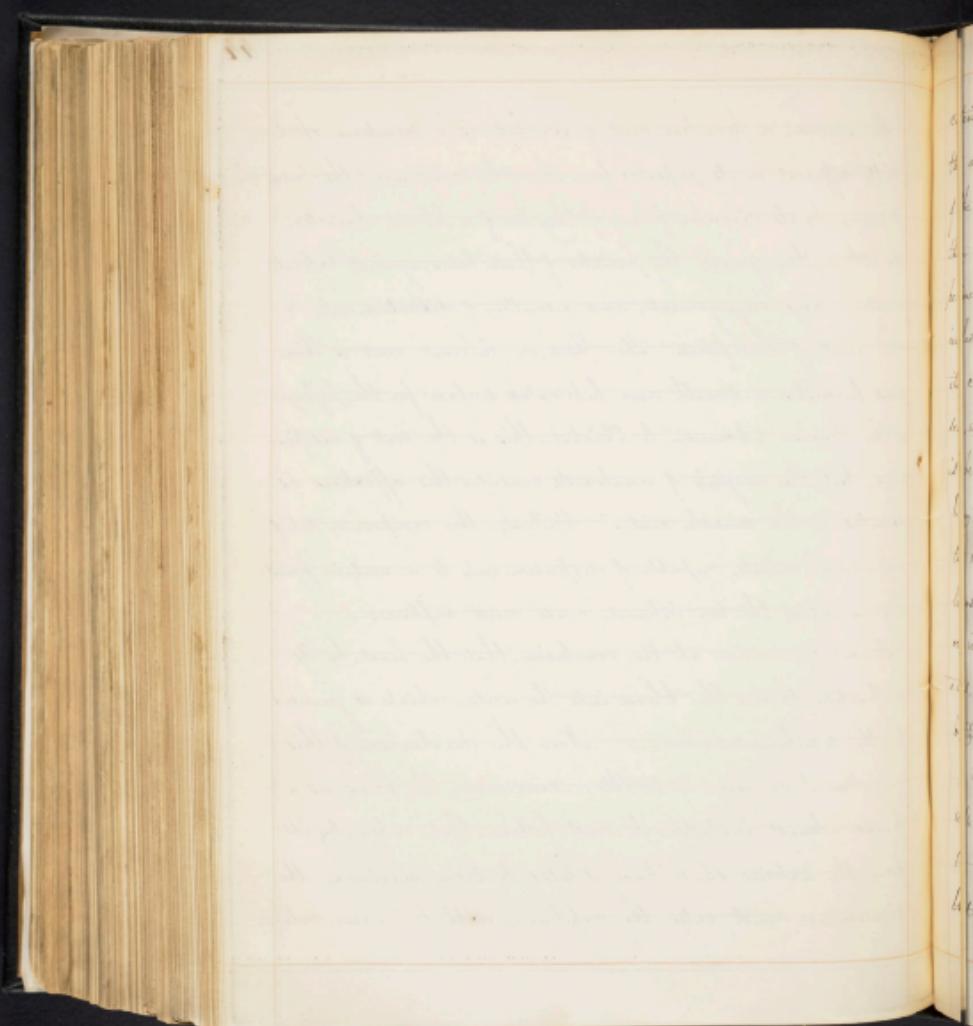
tumks; it constantly diminishes: a circumstance that distinguishes it essentially from the internal membrane, which I have found a smooth and thick in the thick artery, as in the aorta". Pichot observes, that "the muscular texture, is soft, loose, and very extensible; the arterial texture, on the contrary, is firm and solid, breaking before it yields." In addition to this he has endeavoured to shew, that in almost every point of view, there is a real difference, in the nature of the two substances, perhaps only excepting the fibrous appearance, presented by both; these fibres he affects to be circular.

From the best data, that I can collect, among the diversity of opinion, it appears to me, most probable, that the arteries are a series of tubes, composed of 3 membranes, the first, or condensed cellular tissue, imparting strength, and elasticity to the structure, and at the same time, resisting those substances which are calculated to replace or break it, as hydrius, anerius &c. serving also as a smooth, and lubricous envelope for the performance of its movements, in extension and locomotion, and, as an elastic protection, when violently put upon the stretch.



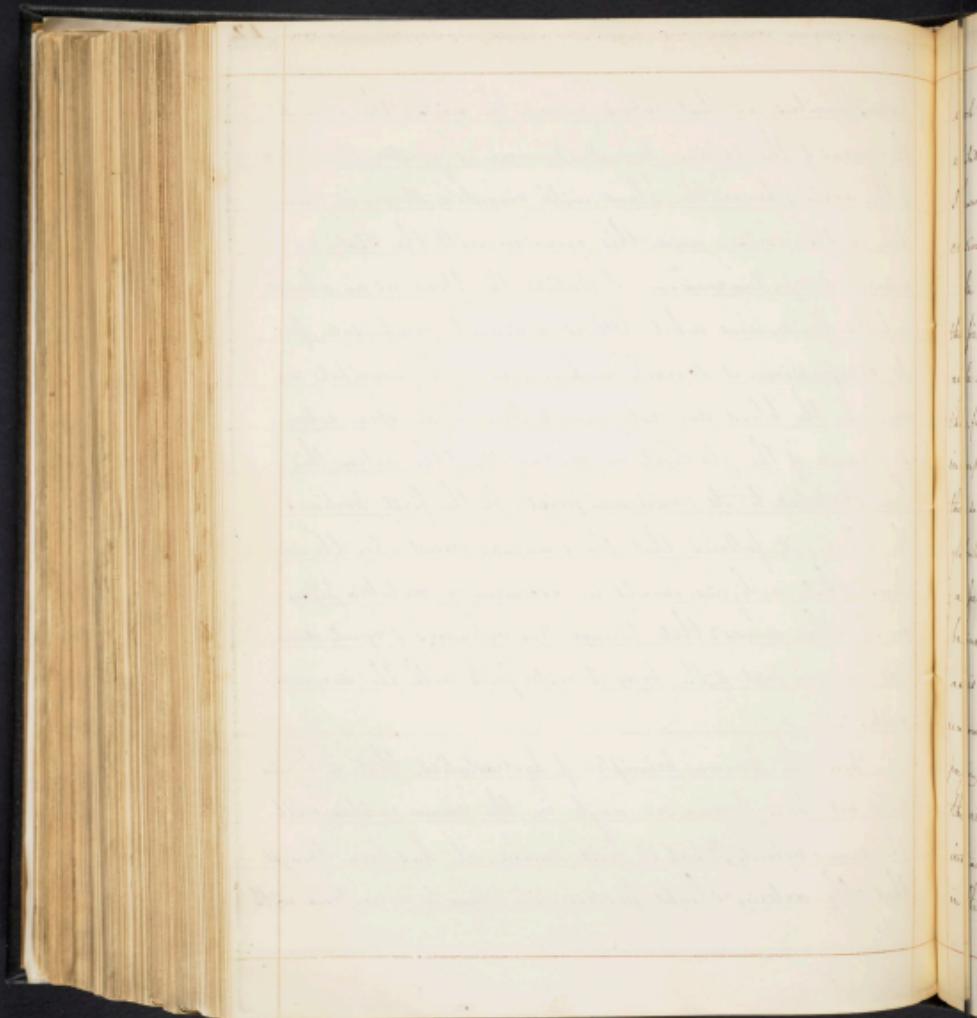
The second, or peculiar coat of Bichat, is a membrane, often
tightly different in its properties from the other membranes of the body,
serving by its circular fibres, if they be of a fibrous character,
to strengthen, & with the parietes of those tubes, against lateral
pressure, and engorgement, and admitting of distension, only to
the limit of those fibres. The third, or internal coat is thin,
and furnishes a smooth and lubricated surface for the passage
of the blood. According to Bichat, this is the seat of affection
- but the majority of anatomists consider this affection as
located in the middle coat. Merely, they compose a set of
cylindrical vessels, capable of distension, only to a certain point,
beyond which the two internal coats must rupture.

Hence, we arrive at the conclusion, that the heart, by its
contraction, throws the blood into the aorta, which is guarded
by the semilunar valves. Now the mechanism of this
operation, I conceive to be this: considering the blood, as a
lique almost inelastic, it must follow, that when, by its
force the arteries shall have dilated to their maximum, the
remainder must enter the capillaries with the same velocity,



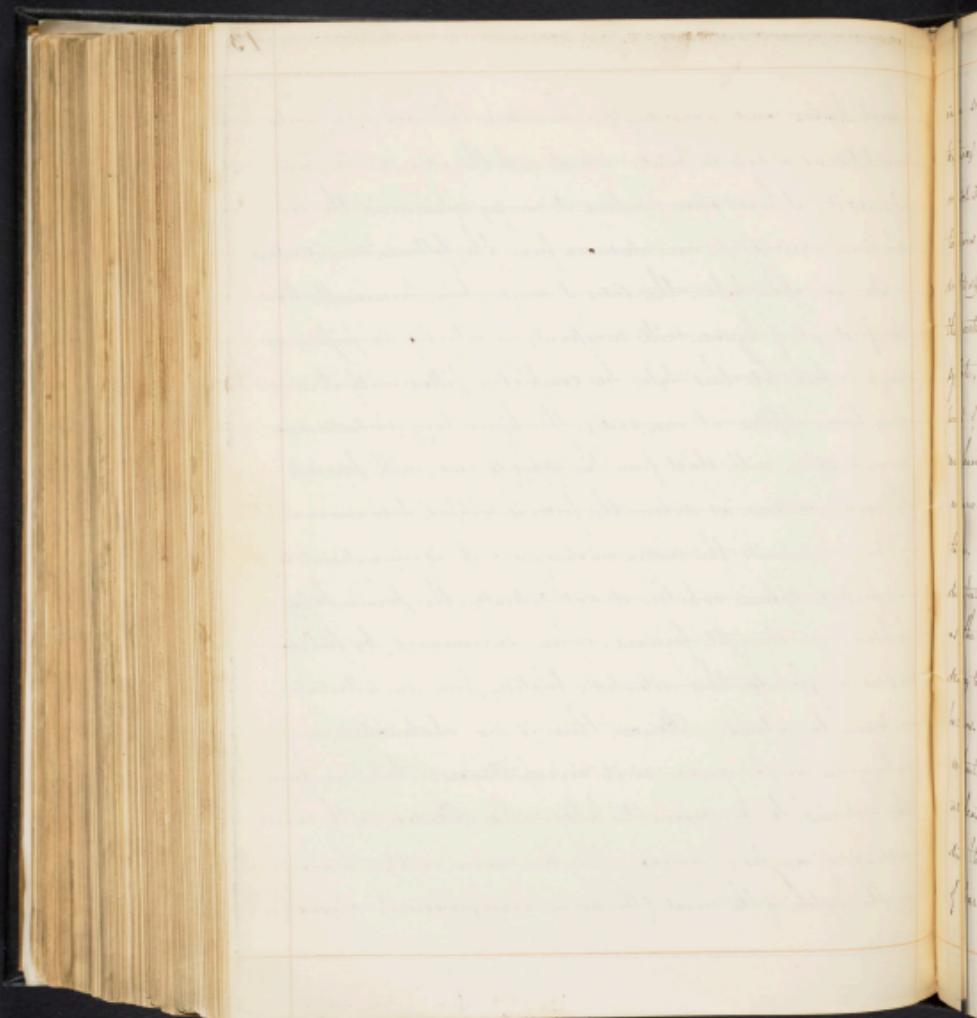
extens prius, as that which moves in the aorta; the sum of the areas of the extreme branches however, is greater than that of the aorta; hence the blood will circulate slower in them than in the aorta, and this coincides, with the 51st. experiment of Spallanzani. — I consider the blood as an almost inelastic fluid, and what little it requires to compensate, for its compression, it scarcely worth naming: the principal reason, why the blood does not cease to flow in an open artery, is because of the elasticity or contractility of the artery; this being stretched to its maximum point, by the first portion of the blood, it follows, that the remainder must obey the same laws, that a liquid would in ascending a metallic pipe, or in other words, that through two cylinders of equal diameter, in any part of the body, it will pass with the same velocity.

Upon the known principle of hydrostatics, that a liquid will not pass beyond an angle in the same ratio, with the same velocity, ⁱⁿ which it first moves, it has been thought that the arteries should possess dilatations to correspond with

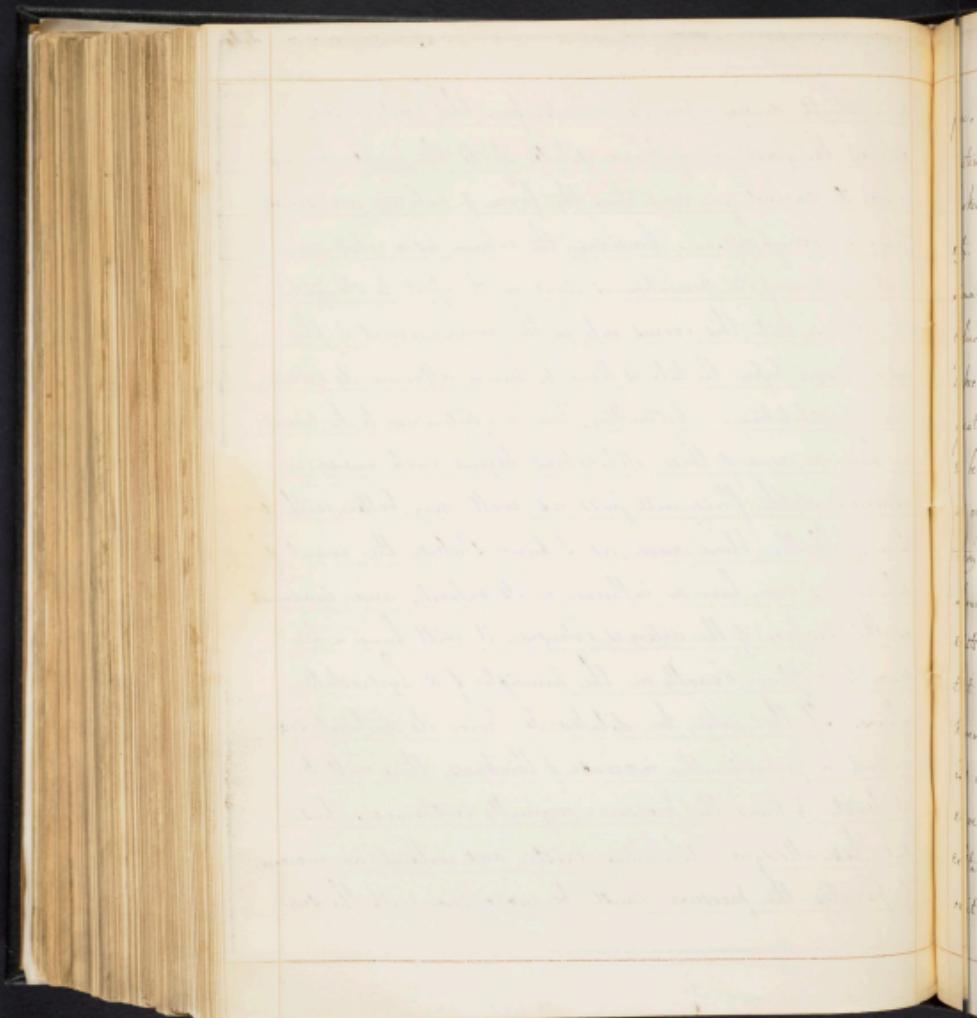


each turn: and accordingly, I have seen the arch of the aorta exhibited at a case in point: I had with the idea, at the time I saw it, I have since resolved it in my mind, and the conclusions arrived at, are deduced from the following considerations:

In an open tube, the sides of course, being permanently fixed, the first jet of liquid, will necessarily be retarded in passing an angle: but let this tube be completely filled with it, and then force applied at one end; the liquid being inelastic, and incompressible, will start from the opposite end, with precisely the same motion, as to where the force is applied, because each globule transmits the motion unchanged: it is immaterial to a perfect sphere whether it act laterally, the power being behind, or straight forward, when surrounded by water as is a globule thus situated, friction being an attribute unknown to atoms. Hence, there is no obstruction in passing an angle under such circumstances: but we know the arteries to be moveable tubes, and alveolated with curves instead of angles: moreover, they are never empty: hence, in the systole of the heart, (the aorta having previously closed)



in a slight degree upon its contents, from the contractility of
tissues; the first jet of blood, dilates it to the point, beyond
which it cannot go, and then the force & velocity are simul-
taneous throughout. Considering the column as a whole, un-
doubtedly, some of its momentum is spent in the effort to straighten
the arteries, but this occurs only in the commencement of the
stroke, and before the tube is fixed by having attained its extreme
point of dilatation. Assuming these considerations to be correct
we have no room of these dilatations, beyond each curve in-
duced at the place where pass as well, say, better, without
them. If the blood move, as I have stated, the want of
dilatations can have no influence on its velocity, and instead
as the surface of the artery is extended, it will have a ten-
dency to rupture, exactly on the principles of a hydrostatics
barrel. If the artery be dilated to twice its natural size
without a proportionable increase of thickness, there will be
at least 4 times the pressure, originally sustained; thus,
that these allodys dilatations exist, and without an increase
of paroxysm, the pressure must be increased with the cur-

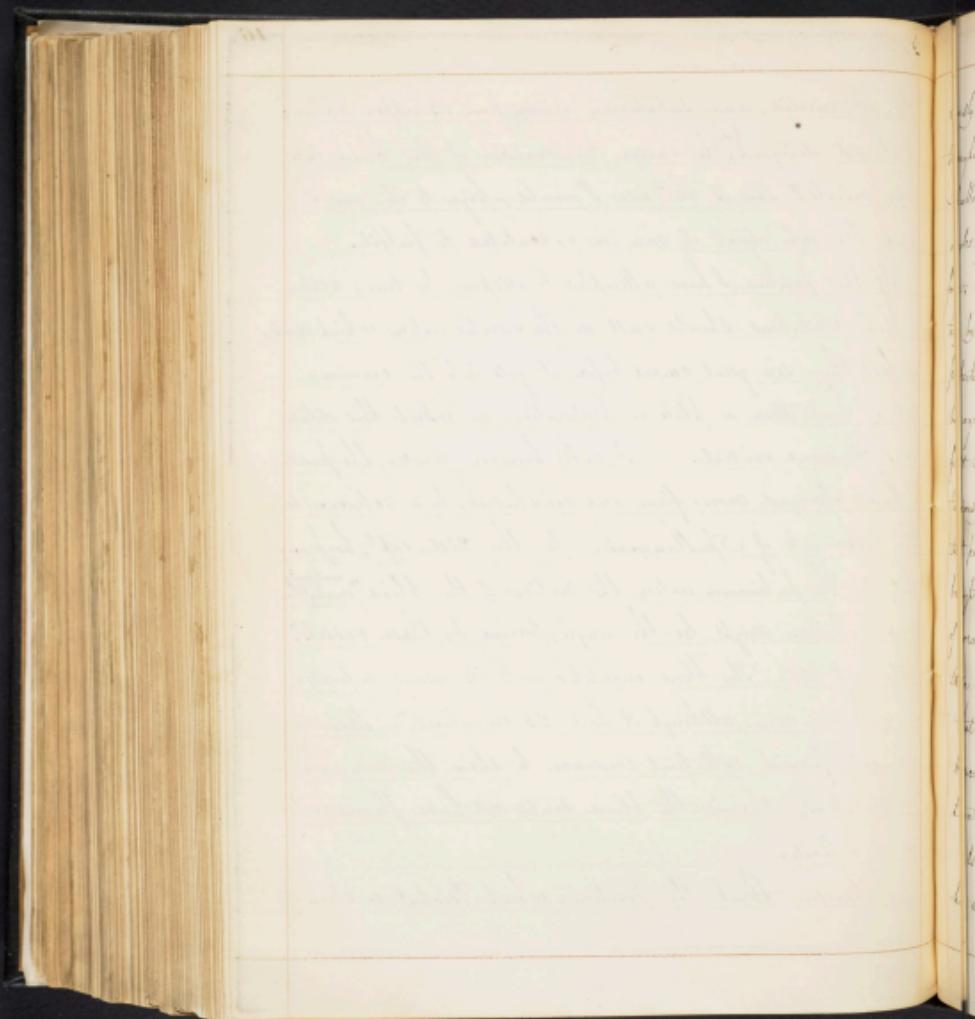


face, and of course the tendency to rupture. Even were the arteries complete being canals, protecting us mortally, the unbrokenness of the tenuissimus colicaria, & its non-clastic property, would subject it to the same laws: the ligament moves simultaneously in all its parts, when confined to a regular cylinder. — It is very true that the aorta possesses, especially in old subjects, a considerable dilatation at its great curve; but, of the preparations I have examined, are to be relied on, this dilatation does not correspond with what it ought to exhibit, were its object as stated in the preceding theory. In an angular tube, the increased circumference should be just beyond the bend, because the impediment exists at its extreme boundary, and until the ligament has reached that impediment it loses but little of its momentum. This however does not hold in the aorta, for the dilatation exists immediately in its curve, and is lost even before that curve is completed. How then can this dilatation facilitate the passage of the blood? that it does, is evident, or it would not exist. Look at the insominate, the

the left carotid, and subclavian arising from its upper portion; is it not designed ^{for} the easier transmission of the blood into those vessels? This is the use I would assign to it, and I think the only object it can be calculated to fulfil.

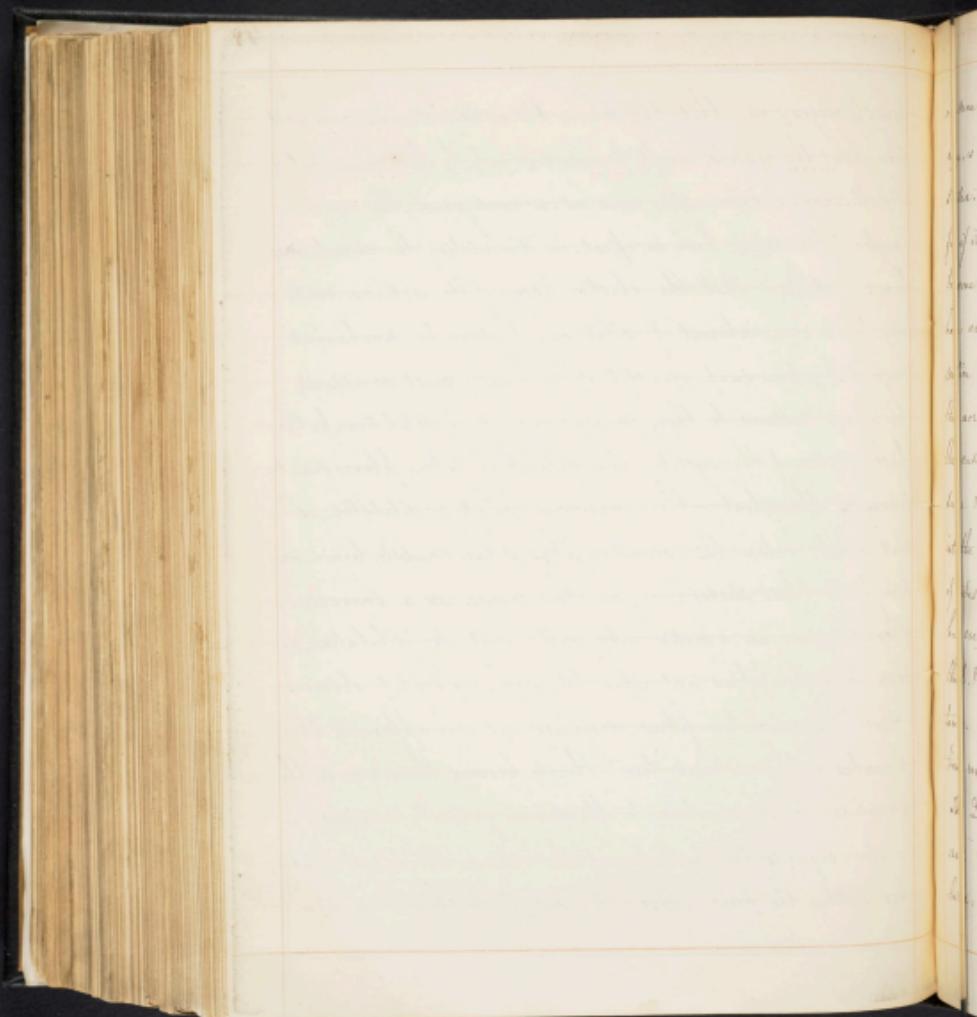
If the position I have attempted to disprove be true, certainly these dilatations should exist in the carotid arteries, which makes no less than six great curves before it gets into the cranium; yet I ~~have seen~~ seen a plate or preparation, in which this dilatation rendered evident. I will however re-enter the position I have affirmed more firm and consolidated, by a reference to the experiment of Spallanzani: In the 21st. edit., he proves that in the pulmonary artery, the motion of the blood "unfolds the turns, whatever might be the angle, formed by these vessels." Experiment 65d. "The blood circulated with its usual velocity in an intestinal vein, although it had 25 curvatures." These experiments furnish collateral evidence to show the non-existence of dilatations, otherwise the blood could not have flowed with usual velocity.

I therefore think the position, which Biobat so stren-

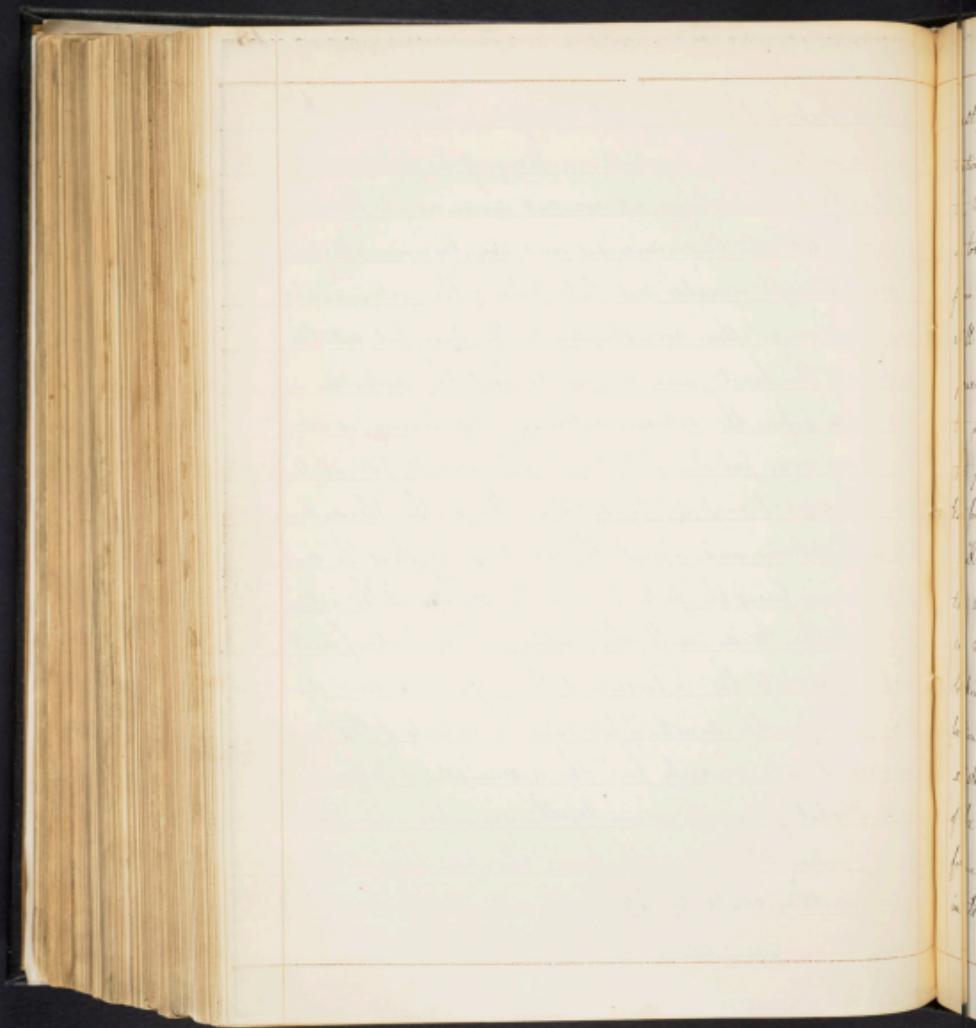


would urges, me, that the blood had a simultaneous movement throughout the vessels, only forced, not only by his own, but Spallanzani's experiments, and at a consequence, the curvilinear angles of the arteries, have no effect, in diminishing the circulatory force; also, that the elastic tissue of the arteries, contracting by its own inherent & vital power, it may be, mechanical properties, upon each stroke of the heart, must necessarily be again restored to their maximum point of dilatation, by the first motion of the systole, this dilatation taking place simultaneously throughout: the maximum point of dilatation, is that point, when the circular fibres of the middle tunic, are brought to their stretch; or, in other words, as a succession of cords upon an elastic tube will limit its dilatation, so these circular fibres act upon the artery. Bichat observes that "the circular fibres diminish, as we approach the branches of the arterial tree," thereby proving their use in the structure to be contrary, to the opinion generally received.

As regards the pulsation of the arteries, Bichat I think has settled the point, that they pulsate by their locomotion

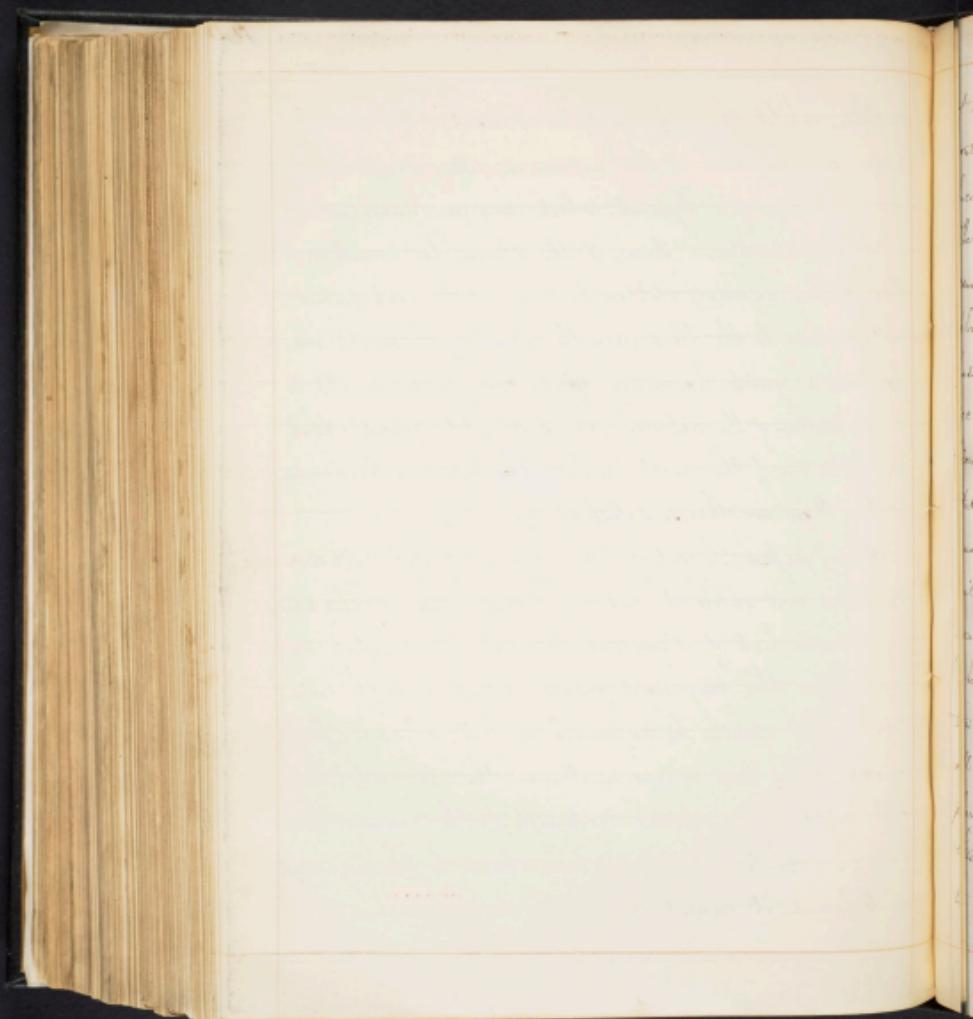


or more properly their attempt to straighten; and here, by the way, is another strong argument, in favour of his position, above stated, that the column at one end moves, as at the other, for if it did not, this univocal and simultaneous effort to become straight would not take place: the artery would have an undulation corresponding to the force, but not the motion of the heart, and we should feel the pulsation in the aorta before the extreme arteries. This however, is not the case: every pulsation of the heart is universally felt at the same moment throughout the system. Hence, the blood, driven into the capillaries, and against the constrictures, lengthens the series of tubes and forms the pulse: but the structure of the artery has every thing to do with this motion: it is elastic, fine & thick, & transmits the impression of the pulsation to some distance. Were the paries of the veins the subjects of this motion, we should scarcely feel the transmission of its force. His Ditchat proved by joining together an artery and a vein, and making the blood of the former circulate through the latter: nothing could be felt in the vein, but a kind of

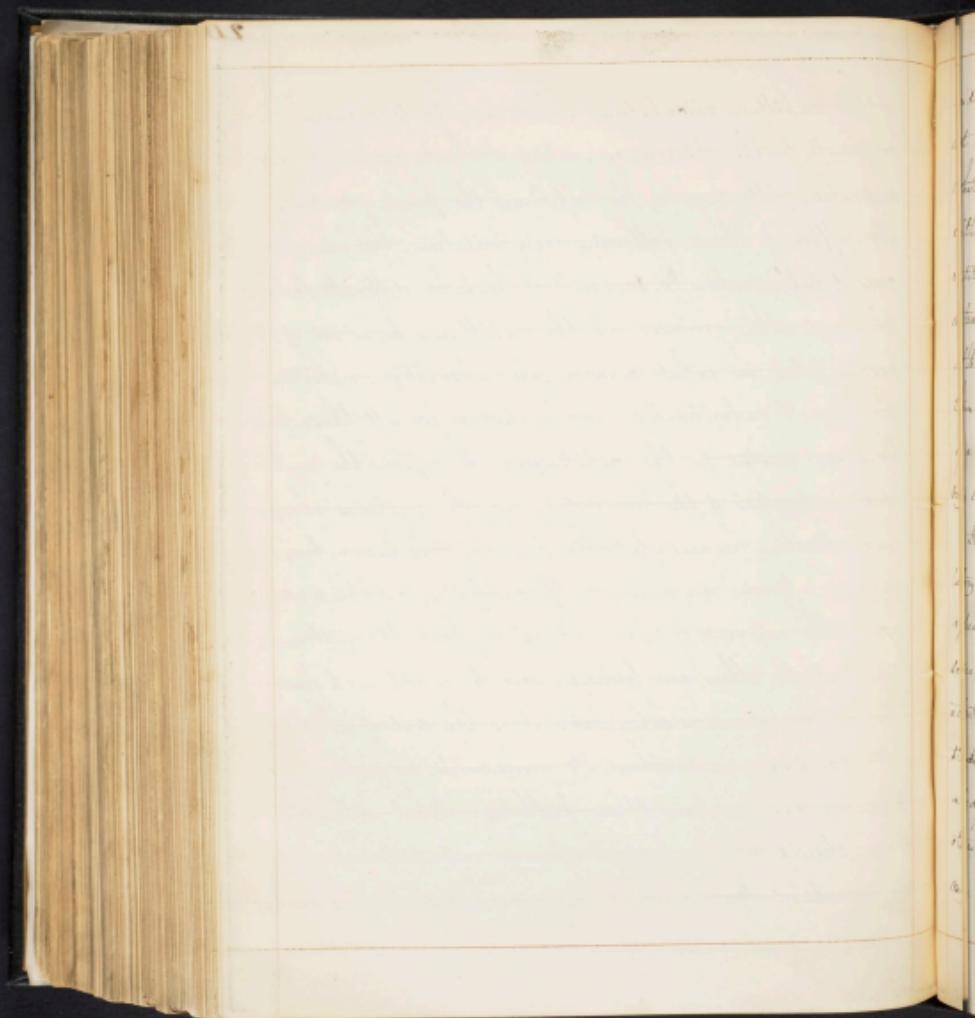


pulsing, whilst the artery pulsates as usual. The best illustration we can have of the arteries *in situ*, is afforded by the broken pipe of a hydrant, which may run uncovered in a tortuous direction. Here, if the stream be permitted to flow, & then suddenly stopped by means of the cock, (which will suffice to the blow given the column by the heart), we perceive a quick locomotive effort, corresponding exactly to the pulsation of the arteries. It is on this principle that the pulsation of the heart against the ribs can be accounted for, & so no other so satisfactorily.

Having passed the set of tubes denominated the arteries, the blood next enters the capillary system: and, at this stage we have no lack of discordant opinions: the mechanicians looked upon this congeries of vessels, as superior in the circulation: an opinion by no means the least plausible, formerly existed, & has been received in France, that the dilatations of the right heart affected materially by the vacuum it formed. Whatever value we may attach to the arguments in its favour, it cannot explain the various phenomena

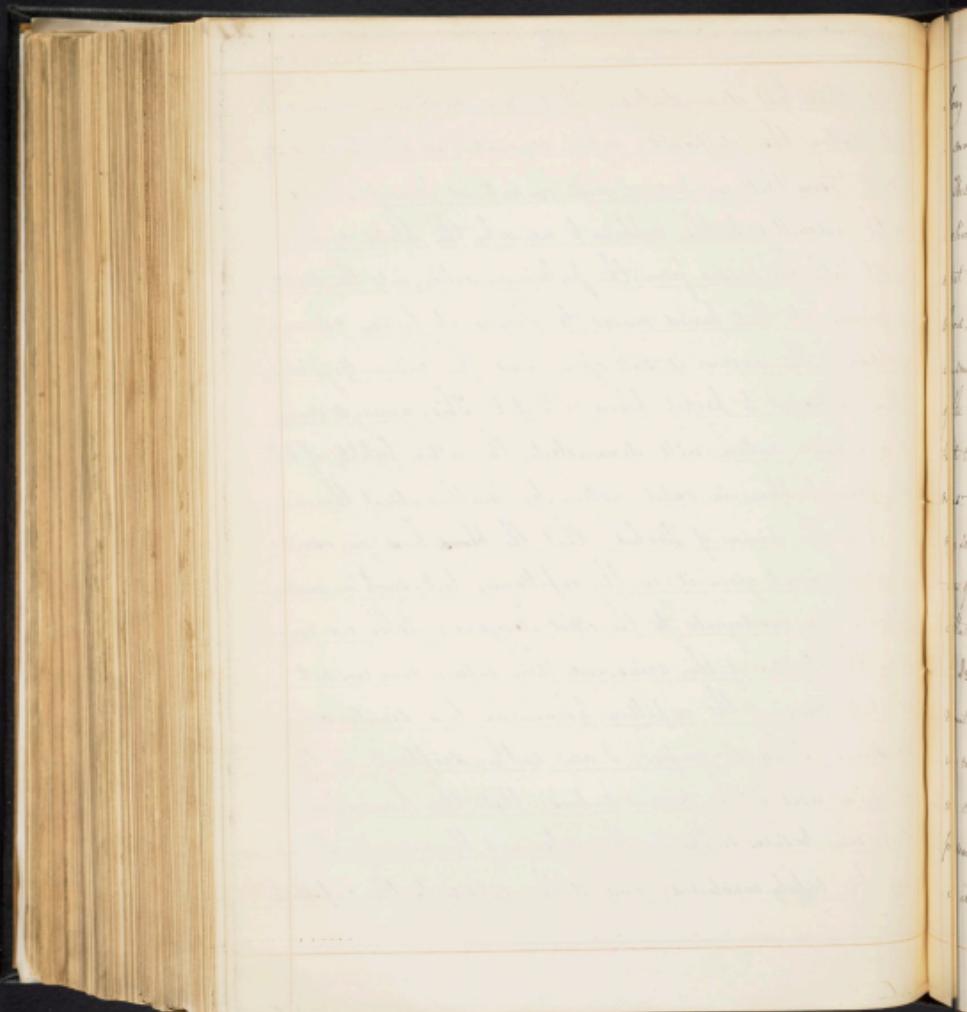


of the capillary circulation: There are facts occurring continually to the observing eye, which I think cannot be explained, without giving the capillaries the power of motion. The efflux of blood following every irritation, the phenomenon of inflammation &c. &c. will I think be difficult to explain on other grounds. If the capillaries be a set of passive tubes, in what manner, are absorption, nutrition, secretion, & calorification accomplished, for all these functions are seated in the capillaries. To explain the simultaneous functions of the living system, and the mysterious changes and alterations unceasingly taking place in the human body, without allowing an agency to the capillaries, is I think, beyond the ingenuity of man. It is in fact the system, on which all the others are founded, and to which each function in the economy is subordinate: it is the seat of almost all diseases, and without its groundwork, no rational explanation can be given of their pathology. What attention then should not be bestowed upon so important a part of the machine? Yet there ^{are} few facts of which so little is known,



and still less demonstrated. That mere mechanical laws will not solve the difficulties which encounter us here is evident. What theory that we possess, will on rational principles, and with admitted truths, explain to us, why the blood which until birth has passed from the pulmonary artery, into the ductus arteriosus, at that period ceases to flow in its former channel, although the avenue is still open, and the vis-a-tense more than sufficient to propel blood into it? This, among a many of a similar nature, will demonstrate the utter futility of solving every problem, in vital action, by mathematical theories.

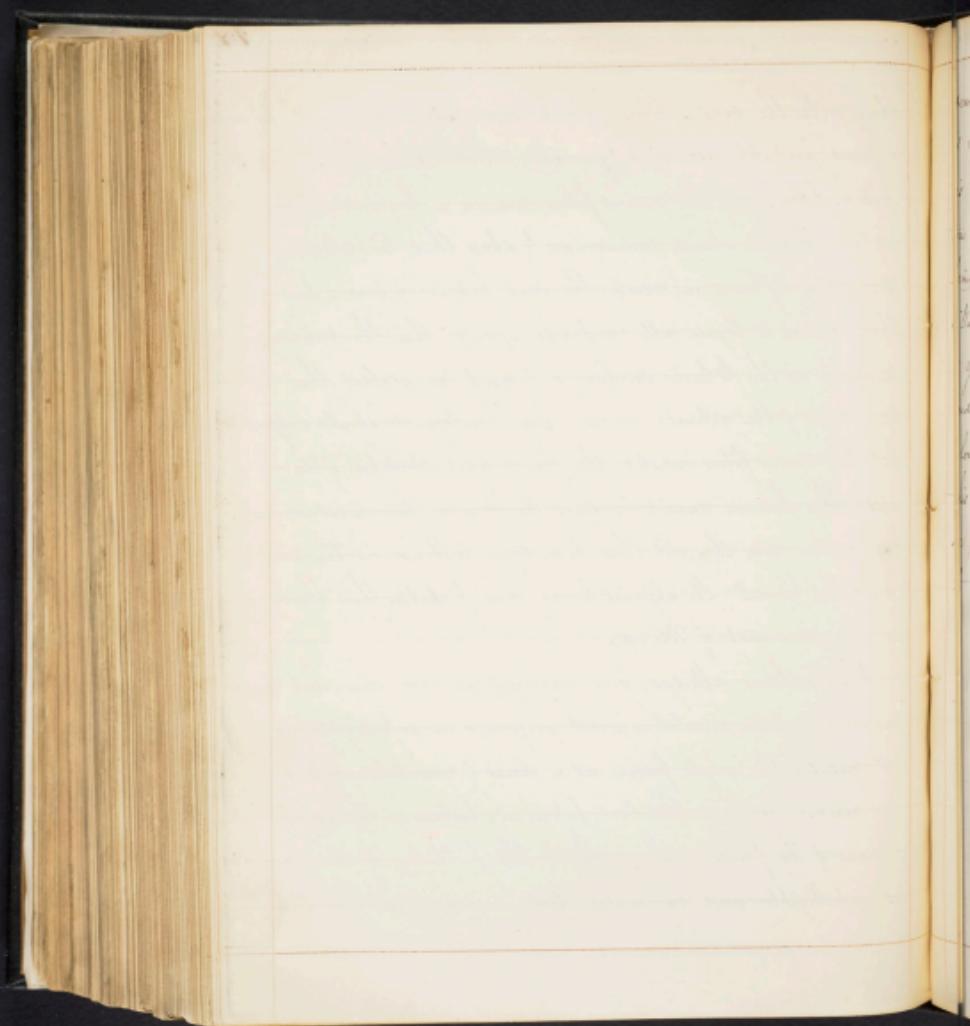
It is the opinion of Viechot, that the blood has an oscillatory movement given it, in the capillaries; but such a motion appears very inadequate to the effect described: When we consider the structure of the veins, and their valves, may we not attribute some of the capillary phenomena to a similar cause? I must confess, I am rather sceptical, on the alleged uses of the venous valves: that they have some other use besides supporting the column of blood surely, I think can be safely concluded: and if they extend to the capillaries



along with the venous fibres, I think some future day, will assign a more probable use than is generally attributed to them.

These latter, viz: the venous fibres, run in a longitudinal direction. I have already endeavoured to show that the arteries exert their influence in resisting the great lateral pressure of the blood, which is beyond all comparison greater than the vertical, insomuch as the lateral surface is of much more extent than that of the ends of the arteries: reasoning from analogy, we should suppose that the venous fibres resisted the longitudinal stretching of the veins: this however cannot be since the force in that direction is very small: may they not then have some influence in the motion of the blood? It appears to me more probable, than the oscillatory movement of Pictet.

Dr. Jackson alledges, from microscopical observation, that the minute circulation is not performed in vessels: unless we consider the whole frame, as a series of convoluted vessels, we cannot, without this fact before us, believe in the omnipresence of the fluids: and with it the pathology of disease is intelligible and rational: Yet it is certain that the



serous capillaries must have a constrictment, which he thinks
it is not the case. This however, though doubtless correct,
is but the connecting link: and without a cause of some-
thing to the serous blood, the chain of explanation is far from
being complete: whether it be from capillary attraction, or
vibratory movement, muscular contraction, or some other power
is yet to be determined. But the rapid march of Science,
and the fresh discoveries continually breaking in upon her
clouds of Error and Ignorance, lead me to hope, that
this with many other un unravelled intricacies, will ere long
be plucked from among the arcana of Nature, and added
to the well earned laurels of Medicine.—

